Hamstring Muscle Activation during Maximum Isometric Tests in Individuals with Anterior Cruciate Ligament Reconstruction and Controls

Evagelos Karagiannidis¹, Glykeria Patsika², Eleftherios Kellis³, Nikiforos Galanis⁴ & Baltzopoulos Vasilios⁵

¹,²,³Laboratory of Neuromechanics, Department of Physical Education and Sport Sciences at Serres, Aristotle University of Thessaloniki
⁴Division of Sports Medicine, Department of Orthopaedics, Papageorgiou General Hospital, Medical School, Aristotle University of Thessaloniki, Greece.

Abstract: Although changes in hamstring muscle morphology after anterior cruciate ligament reconstruction (ACLR) using a semitendinosus autograft are recognized, alterations in muscle activation during isometric flexion in the harvested limb have not been extensively studied. The purpose of this study was to compare knee muscle activation patterns during a maximal isometric knee flexion in people who underwent ACL reconstruction. Surface electromyography (EMG) was sampled from semitendinosus and biceps femoris muscles of 8 participants 1-6 years after ACLR and 8 matched controls (CTRL). Peak normalized muscle activation levels and torque were identified during maximal isometric test. No significant differences were found for the EMG and torque values between anterior cruciate ligament reconstructed group and controls. This study demonstrated that the torque angle was shifted to a shallow angle, suggesting that the hamstring strength was weaker as the flexion angle increases. However, there were not significant differences concerning the torque and EMG. This indicates that ST and BF recover after harvesting in most people one year or more after ACL reconstruction.

1. Introduction

The semitendinosus (ST) tendon is widely used as autograft for anterior cruciate ligament reconstruction (ACLR). The use of ST tendon has been reported to have some advantages such as suitable morphology and lower donor-site morbidity [63,18]. After harvesting for ACL reconstruction the hamstring tendon regenerates in most people and becomes similar to normal [15,23,32,33,41,54,55].

Previous research findings are controversial indicating considerable decrease of knee flexion torque and strength after harvesting the ST for ACLR [67,69,21,47] while others reported the opposite [40,48,64,76,17,51].

Little information is available on the maximal isometric knee flexion between people with ACLR and controls concerning activation and torque on ST tendon–harvested limb relationship between people with ACLR and controls [9,13,62,70].

Makihara [53] suggests that atrophy and shortening of the ST and the abnormal attachment site of the regenerated ST tendon have an influence on the decrease of knee flexion torque. These changes in the ST as a muscle-tendon complex could be reasonably assumed to be a factor causing torque and activation deficits in knee flexion [57].

This study aimed to assess and compare the torque and electromyographic (EMG) activity of semitendinosus and biceps femoris muscles during isometric knee flexion efforts between individuals who underwent ACL reconstruction and controls.

2. Methods

2.1. Subject

A total of 16 subjects (12 males and 4 females, age 28.56 ± 7,7144 years, mass 75.93 ± 11,59 kg, height 1.75 ± 7,26 cm) volunteered to participate in this study after signing written informed consent. Eight participants (6 male 2 female) were healthy and they had no injury of the lower limbs including history of hamstring strain or any other muscle or ligamentous injury of the knee and 8 participants (6 male 2 female) underwent ACL reconstruction with semitendinosus tendon graft. The selection criteria were as follows: a. isolated ACL rupture with absence of any injury of other structures, b. ACL reconstruction with a semitendinosus tendon autograft technique, c. surgery occurred more than 12 months prior to this study, d. followed the same postoperative rehabilitation by the same medical team and e. no history of neurological disease, or vestibular or visual disturbance, f. any other episode of instability after ACL reconstruction surgery (Kellis 2013). The study was approved by the University’s Institutional Review Board.
2.2. Instrumentation

Maximum isometric tests were performed on a Cybex isokinetic dynamometer (Humac Norm, Cybex CSMI, Stoughton, MA, U.S.A.). Electromyographic (EMG) measurements were recorded using a remote EMG (Biopac System Inc., Goleta, CA, USA). A Biopac MP100 Acquisition Unit (Biopac Systems Inc, Goleta, California), sampling at 1000 Hz, were used to collect angular position, moment, and EMG signals. The data were analyzed using AcqKnowledge (Version 3.9.1., Biopac System Inc., Goleta, CA, USA).

2.3. Experimental Procedure

The skin in the application area, was shaved and then cleaned with alcohol wipes to remove any dead cells. Bipolar Ag-Ag/Cl surface EMG electrodes (diameter 2 cm, distance 1 cm) were placed according to S.E.N.I.A.M. recommendations. Electrodes were placed over the long head of the biceps femoris (BF), half way on the line between the ischial tuberosity and the head of the fibula and over the semitendinosus (ST), half way on the line between the ischial tuberosity and proximal tibia. The ground electrode was placed on a bony prominence and its position was not altered during any of the testing procedures.

Before the testing protocol, subjects were familiarized with the isokinetic dynamometer. The subjects were positioned in a prone position on the chair with hip and knee flexion angle at 0° (hip knee full extension). The thigh, pelvis, and trunk were stabilized with straps. The axis of knee rotation was aligned with the lateral femoral condyle. The familiarization and warm-up contained 5 submaximal and 3 maximal repetitions at each testing condition of the protocol. During testing, the subjects performed 5 maximal isometric efforts of the knee flexors from knee flexion angles of 0° and 45°. The duration of the contraction was 5 sec and subjects were instructed to exert force as fast and as hard as they can. An interval of 2 min between tests was used to minimize fatigue effect. The position of the electrodes did not change during the test, and all tests were performed by the same investigator.

2.4. Data analysis

Maximum isometric torque was compared between the two groups. For comparison of EMG values between the normal and ACL reconstructed limbs, the ratio of the EMG value at 0° of knee flexion relative to that at 45° was used to account for differences in electrode placement [52]. In addition, the isometric torque to EMG ratio [37] was used to compare the torque between the two groups. Statistical analysis was performed using Statistical Package for the Social Sciences (SPSS 23.0 Inc., Chicago, IL). A paired t-test was used to test for differences in EMG ratio values between the two groups. A two-way (2 X 2) Analysis of variance (ANOVA) (2x2) was used to compare torque between angular positions and groups. A similar ANOVA test was used to examine torque / EMG ratio values. The level of significance was set at p < 0.05.

3. Results

The torque values for each group are presented in Table 1. The ANOVA showed that there was not a statistically significant Group X Angle interaction on maximum isometric torque (F1, 10 = 0.007, p = 0.934). In addition, the main effect for Group was also not statistically significant (F1, 10 = 1.480, p = 0.24). The 0° to 45° EMG ratio is presented in Figure 2. The t-tests showed that there was no statistically significant group difference in BF (t14=1.14, p=0.25) and ST (t14=1.49, p=0.25) ratio.

The torque / EMG ratio values for each group are presented in Table 4. There was not a statistically significant Group X Angle interaction on torque / EMG ratio for both BF (F1, 10 = 0.235, p = 0.63) and ST (F1, 10 = 0.007, p = 0.93). However, the main effect for Group was statistically significant for the BF (F1, 10 = 4.85, p = 0.04) and ST (F1, 10 = 13.26, p = 0.003).

Table 1. Isometric knee flexion (Mean and SD) torque, angular velocities, in ACL reconstructed group and controls.

<table>
<thead>
<tr>
<th>Angle</th>
<th>ACLR</th>
<th>Ctrl</th>
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<tbody>
<tr>
<td>0°</td>
<td>97,91 (32,66)</td>
<td>78,67 (46,85)</td>
</tr>
<tr>
<td>45°</td>
<td>76,29 (20,19)</td>
<td>55,74 (39,91)</td>
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Table 2. The ratio of EMG valu

<table>
<thead>
<tr>
<th>BF</th>
<th>ST</th>
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<tbody>
<tr>
<td>ACLR</td>
<td>Ctrl</td>
</tr>
<tr>
<td>0°</td>
<td>18799,73* (22816,18)</td>
</tr>
<tr>
<td>4°</td>
<td>16156,17* (16607,69)</td>
</tr>
</tbody>
</table>

Table 3. Isometric knee flexion (Mean and SD), Biceps femoris and Semitendinosus electromyography (EMG) ratio (0deg /45deg) at different angular velocities, in ACL reconstructed group and controls.

4. Discussion

The results of this study were that the ACLR group showed no differences in torque [57,69,7,65,1,48,76,52]. Also no significant differences were found in EMG values [52,16]. Although the peak knee-flexion torque of the ST tendon-harvested limb could be recovered near to normal [7], muscle performances by a knee after ACL reconstruction are not so simple and can be evaluated only by peak torque [1]. Previews research reported similar outcomes for the measured flexion angles and more specific.

Nishino et al. [57] investigated the relationship between deficits in knee-flexion torque and morphological changes in the semitendinosus muscle-tendon complex after harvesting the ST for ACL recording the isometric knee-flexion torque at 45o and 90o in 23 patients. The regeneration of the semitendinosus tendon-like structure was confirmed in 21 of the 23 patients. For the patients with regeneration of the ST tendon-like structure at the ST tendon–harvested site, knee-flexion torque of the ST tendon–harvested limb was recovered at shallow knee-flexion angles.

Tashiro et al. [69] measured maximum isometric knee flexion torque at 70° and 90° in both seated and prone positions. They indicated decreased recovery of hamstring muscle strength at knee flexion angles of 70° or higher even 18 months after the reconstruction.

Segawa et al. [37] investigated the influence of harvesting semitendinosus and gracilis tendons on the rotational muscle strength of the limb after anterior cruciate ligament (ACL) reconstruction. The peak isokinetic torques for extension, flexion, internal rotation, and external rotation were measured before and 12 months after ACL reconstruction. The mean isokinetic peak torque of the involved limb in extension recovered 12 months after ACL reconstruction.

Adern et al. [7] in a review study demonstrated that the differences between the ACLR and control groups were not statistically significant.

Lipscomb et al. [48] evaluated postoperative hamstring strength on 51 patients who underwent ACL reconstruction using the ST or a combination of the ST and G. They reported that peak torque value of hamstring strength was recovered to an average of 99% compared to the normal knee.

Yasuda et al. [76] performed a prospective randomized study with 65 patients who underwent ACL reconstruction using the ST and G harvested from the ipsilateral or contralateral knee. They reported that the peak torque value of the hamstring that was harvested from the contralateral knee was 99% of the preoperative value 1 year after harvesting.

Makihara et al. [52] aimed to investigate the decrease of deep knee flexion torque after anterior cruciate ligament (ACL) reconstruction, using a semitendinosus (and gracilis) tendon. The flexion torque and EMG of the hamstrings were measured in both limbs of 16 patients after ACL reconstruction. During knee flexion torque measurement, it was found that the peak torque of the ACL reconstructed limb, which occurred at approximately 20°, was recovered sufficiently to 96% of that of the normal knee.
This study also revealed a decrease in both the isokinetic and isometric knee flexion torque, during knee flexion at 60° and beyond. Concerning EMG values Makihara et al. found significant differences of both limbs as well as the knee flexion angle was increased but not between ACLR and control.

Nicol et al. [16] compared knee extension and flexion torques and electromyographic (EMG) activity of normal and anterior cruciate ligament (ACL)-reconstructed knees during maximal unilateral isometric and isokinetic tests performed 4–5 months after ACL reconstruction. Flexion torque deficits were observed in the Op leg of both patient groups and in the non operated leg with minor differences in hamstrings EMG activation.

In research mentioned above it is observed that differences between ACLR groups and controls occurs in larger angles as it is also indicated by Onishi et al. [58]

The muscular recovery after an ACL reconstruction except from the surgery itself, may be affected by numerous factors like the preoperative muscle strength [27], the time between injury and reconstruction [61] and the pre- and post-surgery rehabilitation [6] are some of them [36]. However, hamstrings muscle activation with hamstrings graft 19 months after ACL reconstruction is not different in the operated leg compared to the uninjured leg [35].

This study is one of the very few that investigated ST and BF during MVC after harvesting for ACLR, although has limitations, including a relatively small sample size and the vigorous daily activities of the sample during the post-operative period which can create minor alterations in the subject.

In conclusion this study demonstrated that the torque angle was shifted to a shallow angle, suggesting that the hamstring strength was weaker as the flexion angle increases. However there were not significant differences concerning the torque and EMG. This indicates that ST and BF recovers after harvesting in most people one year or more after ACL reconstruction.

5. References


